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Sagittal abdominal diameter: no advantage compared with other anthropometric measures as a correlate of components of the metabolic syndrome in elderly from the Hoorn Study[1–3]

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ABSTRACT

Background: The sagittal abdominal diameter has been proposed as a useful measure by which to estimate abdominal obesity and as being more strongly related to components of the metabolic syndrome than are other anthropometric measures.

Objective: The objective was to study which anthropometric measure (ie, sagittal abdominal diameter, waist circumference, waist-to-hip ratio, waist-to-height ratio, or body mass index) is the strongest correlate of components of the metabolic syndrome (ie, glucose and lipid concentrations and blood pressure) in the elderly.

Design: The Hoorn Study is a population-based cohort study in older Dutch men and women. Cross-sectional data were analyzed. Age-adjusted Pearson correlations of anthropometric measures with components of the metabolic syndrome were calculated in 826 subjects (389 men, 437 women) aged 56–83 y. Analyses were performed with adjustment for age and stratification for sex and age (<65 or ≥65 y).

Results: No single anthropometric measure was consistently correlated more strongly with components of the metabolic syndrome than were the other measures in either men or women. The associations were generally stronger in younger subjects than in older subjects and in women than in men. For example, the correlation between sagittal abdominal diameter and postload glucose was 0.35 ($P < 0.001$) in younger and 0.14 ($P = 0.051$) in older men, and the correlation between waist circumference and postload glucose was 0.33 ($P < 0.001$) in older women and 0.14 ($P = 0.062$) in older men.

Conclusion: The use of sagittal abdominal diameter has no advantages over simpler and more commonly used anthropometric measures such as the waist circumference in older men and women. *Am J Clin Nutr* 2006;84:995–1002.

KEY WORDS Sagittal abdominal diameter, waist circumference, hip circumference, waist-to-hip ratio, waist-to-height ratio, body mass index, fat distribution, metabolic syndrome, elderly

INTRODUCTION

Obesity is associated with a higher risk of cardiovascular disease (CVD) and diabetes mellitus. Because of the worldwide increasing prevalence of obesity, it has been projected that, by 2020, chronic diseases such as CVD and diabetes mellitus will account for almost three-fourths of all deaths (1). Results from many studies indicate that measures of abdominal fat are better predictors of CVD and diabetes mellitus than is total adiposity as assessed by the body mass index (BMI; in kg/m^2) in adults (2–9). The higher risk of CVD and diabetes mellitus associated with abdominal obesity is usually attributed to greater visceral fat accumulation (10, 11). With abdominal obesity come myriad metabolic disturbances such as elevated concentrations of plasma triacyglycerol, glucose, and insulin; high blood pressure; and low plasma concentrations of HDL cholesterol. The combination of these disturbances is often referred to as the metabolic syndrome (12, 13).

In adult populations, waist-to-hip ratio (WHR) and waist circumference are the most commonly used indicators of abdominal adiposity. Waist circumference has been proposed as a better measure of CVD risk than is WHR, because it correlates more strongly with visceral fat than does WHR (14, 15). Sagittal abdominal diameter may be an even better predictor of CVD risk than is waist circumference, because it may be a stronger correlate of visceral fat as a result of the movement of subcutaneous fat to the sides of the waist when the measurement is taken. Several investigators, however, have identified WHR as a better predictor of CVD and diabetes mellitus than is waist circumference (2, 3, 16, 17). This unexpected result may be due to a relatively protective role of peripheral fat tissue and muscle mass at the hips (18, 19).

Aging is associated with a decrease in height (20, 21), a more central fat distribution (22, 23), and a loss of muscle mass (sarcopenia) (24). As a result, one should be cautious when interpreting associations between anthropometric measures and metabolic risk in the elderly.

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Indirect anthropometric estimates of body composition have proven useful for clinical practice and epidemiologic surveys because they are simple, noninvasive, and cheap. However, studies that compare the association between anthropometric variables and CVD risk factors are scarce, particularly in older subjects. Therefore, the principal aim of this cross-sectional study was to examine which measure (ie, sagittal abdominal diameter, waist circumference, WHR, waist-to-height ratio, or BMI) best reflects the components of the metabolic syndrome in an elderly population. An additional aim was to examine possible age- or sex-based differences in the correlations between anthropometric measures and components of the metabolic syndrome.

SUBJECTS AND METHODS

Subjects

The Hoorn Study is a population-based cohort study of glucose intolerance in a general elderly population in the Netherlands. The baseline examination took place from 1989 until 1992 in 2484 white men and women (aged 50–75 y) and was previously described in detail (25). Between January 1996 and December 1998, a follow-up examination was conducted after a mean interval of 6.4 y. Of the initial cohort, 150 persons had died and 108 had moved away from Hoorn before 1996. One hundred forty other persons were not invited because of logistic reasons. Of the remaining 2086 persons who were invited for the follow-up examination, 1513 (72.5%) participated (8). For the current study, cross-sectional data from this follow-up examination were analyzed after the exclusion of subjects who were using lipid-lowering ($n = 141$), antihypertensive ($n = 347$), or antidiabetic ($n = 28$) medication (some subjects had data missing on >1 variable), because medication use may bias the results and because the anthropometric measurements to predict CVD risk may be most relevant for persons who are not yet taking medication. Subjects with missing sagittal abdominal diameter data (as a result of logistical reasons; $n = 305$) were also excluded. Of the remaining 840 subjects, 14 had ≥1 missing metabolic variable [fasting glucose, triacylglycerols, or glycated hemoglobin (HbA_{1c})] and were also excluded. Therefore, the analyses were performed in 826 subjects (389 men and 437 women).

All participants gave written informed consent. The Ethics Committee of Vrije University Medical Center Amsterdam approved the design of the study.

Measurements

Weight and height were measured while the subjects were barefoot and were wearing light clothing only; BMI was calculated. Sagittal abdominal diameter (in cm) was measured by using a HoltainKahn abdominal caliper (Holtain Ltd, Crymych, United Kingdom) while the subjects were in a supine position. Participants were asked to bend their knees to a 45 ° angle and to keep their feet flat on the examination table. Sagittal abdominal diameter (the distance between the abdomen and the back) was measured as the distance between the blades of the caliper at the end of normal expiration. In a standing position, waist circumference (in cm) was measured at the level midway between the lowest rib margin and the iliac crest, and hip circumference (in cm) was measured at the widest level over the greater trochanters. The mean value of 2 measurements was used in the analyses. WHR was calculated as waist circumference divided by hip circumference, and waist-to-height ratio was calculated as waist circumference divided by height.

Participants underwent a single 75-g oral-glucose-tolerance test. Fasting plasma glucose concentration and glucose concentration 2 h after the glucose load were measured in plasma by using the hexokinase method (Boehringer-Mannheim, Mannheim, Germany). HbA_{1c}, an indicator of long-term glucose concentrations, was measured by using ion-exchange HPLC. HDL cholesterol and triacylglycerols were measured by using enzymatic techniques (Boehringer-Mannheim).

Blood pressure was measured twice with the use of a random-zero sphygmomanometer (Hawksley-Gelman, Lancing, United Kingdom) on the right arm while the subject was sitting. The average of the 2 measurements was used for analyses. Self-reported information on the subjects' current use of lipid-lowering, antihypertensive, and antidiabetic medications was obtained by questionnaires.

Statistical analysis

All statistical analyses were performed separately for men and women because of known differences in body composition. Means and SDs are presented for normally distributed variables, and medians and interquartile ranges are presented for variables with a skewed distribution. The Student's *t* test and the Mann-Whitney *U* test were used to compare differences between the sexes and the age groups.

Intercorrelations of the anthropometric measurements adjusted for age were examined by using partial Pearson correlation analysis. Triacylglycerol concentrations were not normally distributed and were therefore transformed into natural logarithms for statistical tests. We then examined the associations among anthropometric measurements (independent variables) and components of the metabolic syndrome (dependent variables) by performing linear regression analysis, with adjustment for age. Effect modification by age was evaluated by adding product terms (using the continuous age variable × anthropometric variable) to the regression models. Results were stratified by age (<65 or ≥65 y) because some of the associations among anthropometric measurements and components of the metabolic syndrome were significantly modified by age. The associations were also examined by calculating age-adjusted correlations. Because results were similar for the regression analysis and the correlation analysis, we present only the correlations. In further analyses, we also adjusted for BMI to examine the correlations independent of overall obesity.

To calculate the level of waist circumference or sagittal abdominal diameter at which metabolic variables pass their established cutoff values (eg, the level of waist circumference at which the blood pressure reaches the critical value of 140 mm Hg) and to ascertain whether these levels are different for the 2 age groups, we used the age group–specific intercepts and slopes of the linear regression analyses (with adjustment for age). The established cutoffs that we used in the regression formulas were 6.1 mmol/L for fasting glucose and 7.8 mmol/L for postload glucose (26), 1.0 (men) and 1.3 (women) mmol/L for HDL (12), 1.7 mmol/L for triacylglycerol (12), and 140 mm Hg for systolic and 90 mm Hg for diastolic blood pressure (27). For HbA_{1c}, a critical value of 6.5% was used. All statistical analyses were performed by using SPSS for WINDOWS (version 10.1.0; SPSS Inc, Chicago, IL).

TABLE 1
Characteristics of the study population[1]

	Men (n = 389)		Women (n = 437)	
	<65 y old (n = 196)	≥65 y old (n = 193)	<65 y old (n = 231)	≥65 y old (n = 206)
Age (y)	60.5 ± 2.39[2,3]	71.0 ± 4.5	60.5 ± 2.3[3]	71.3 ± 4.5
Anthropometric measures				
Weight (kg)	81.1 ± 12.0[4]	79.3 ± 10.3[4]	71.1 ± 10.0	71.1 ± 10.5
Height (cm)	176.9 ± 6.2[3,4]	175.6 ± 6.5[4]	165.1 ± 5.7[3]	163.3 ± 6.5
BMI (kg/m^2)	25.9 ± 3.3	25.7 ± 2.8[4]	26.1 ± 3.4	26.7 ± 3.7
Sagittal abdominal diameter (cm)	21.0 ± 2.8[4]	21.4 ± 2.5	20.4 ± 2.5[3]	21.4 ± 2.8
Waist girth (cm)	94.1 ± 10.0[3,4]	96.3 ± 8.3[4]	86.4 ± 9.7[4]	89.4 ± 10.9
Hip girth (cm)	99.7 ± 6.4[4]	99.4 ± 5.1[4]	102.3 ± 7.1	103.1 ± 7.6
Waist-to-hip ratio	0.94 ± 0.06[3,4]	0.97 ± 0.06[4]	0.84 ± 0.07[3]	0.87 ± 0.07
Waist-to-height ratio	0.53 ± 0.05[3]	0.55 ± 0.05	0.52 ± 0.06[3]	0.55 ± 0.07
Metabolic variables				
Fasting glucose (mmol/L)	5.98 ± 0.76[4]	6.00 ± 0.73[4]	5.72 ± 0.60	5.84 ± 0.83
Postload glucose (mmol/L)	5.53 ± 1.71[3]	5.99 ± 2.22[4]	5.55 ± 1.40[3]	6.48 ± 2.20
HbA_{1c} (%)	5.33 ± 0.51	5.43 ± 0.54	5.36 ± 0.47	5.44 ± 0.56
Triacylglycerol (mmol/L)	1.30 (1.10–1.70)[5]	1.30 (1.00–1.80)	1.20 (1.00–1.80)	1.30 (1.00–1.70)
HDL cholesterol (mmol/L)	1.20 ± 0.30[4]	1.20 ± 0.34[4]	1.50 ± 0.39	1.49 ± 0.38
Systolic blood pressure (mm Hg)	133.0 ± 18.2[3]	143.8 ± 20.2	134.5 ± 20.6[3]	146.9 ± 21.6
Diastolic blood pressure (mm Hg)	82.0 ± 10.5	81.7 ± 11.4	81.6 ± 10.9	81.0 ± 10.4

[1] HbA_{1c}, glycated hemoglobin.
[2] $\bar{x}$ ± SD (all such values).
[3] Significantly different from other age group by sex, $P < 0.05$ (Student's t test or, in case of skewed distribution, Mann-Whitney U test).
[4] Significantly different from women within an age group, $P < 0.05$ (Student's t test or, in case of skewed distribution, Mann-Whitney U test).
[5] Median; interquartile range in parentheses (all such values).

RESULTS

Characteristics of the study population according to age and sex are shown in **Table 1**. As expected, women had a larger hip circumference, a smaller waist circumference, a lower WHR and higher HDL-cholesterol and lower fasting glucose concentrations than did men, in both age groups. Significant age-related differences were also observed: subjects <65 y old were taller and had a smaller waist circumference, WHR, and waist-to-height ratio than did subjects ≥65 y old. In addition, postload glucose concentrations and systolic blood pressure were substantially higher in older subjects than in their younger counterparts.

Intercorrelations among BMI, sagittal abdominal diameter, waist circumference, WHR, and waist-to-height ratio adjusted for age are presented in **Table 2**. The anthropometric variables were strongly and significantly correlated with each other in both sexes and in both age groups (<65 or ≥65 y).

Age-adjusted correlations between anthropometric measurements and components of the metabolic syndrome, stratified by age, are shown in **Table 3**. No single anthropometric measure had correlations that were substantially higher than the other anthropometric measures. For several components of the metabolic syndrome, but not for postload glucose concentrations, a substantially stronger correlation with anthropometric measurements was observed in younger (<65 y) than in older (≥65 y) subjects. Generally, correlations between anthropometric measures and components of the metabolic syndrome were stronger in women than in men. We also performed these analyses without excluding subjects who were taking antidiabetic, antihypertensive, or lipid-lowering medication,

TABLE 2
Age-adjusted Pearson correlations between anthropometric measures, stratified for age and sex[1]

	Women									
	BMI		SAD		WC		WHR		WHtR	
	<65 y old	≥65 y old	<65 y old	≥65 y old	<65 y old	≥65 y old	<65 y old	≥65 y old	<65 y old	≥65 y old
Men										
BMI	—	—	0.72	0.70	0.80	0.84	0.42	0.51	0.83	0.87
SAD	0.70	0.61	—	—	0.81	0.75	0.58	0.54	0.77	0.71
WC	0.88	0.81	0.79	0.70	—	—	0.78	0.80	0.95	0.95
WHR	0.58	0.48	0.64	0.54	0.83	0.81	—	—	0.80	0.80
WHtR	0.89	0.83	0.75	0.65	0.94	0.91	0.83	0.82	—	—

[1] SAD, sagittal abdominal diameter; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio. All correlations were statistically significant ($P \leq 0.001$).

TABLE 3
Age-adjusted Pearson correlations between anthropometric measurements and components of the metabolic syndrome stratified for age and sex[1]

	Aged <65 y					Aged ≥65 y				
	BMI	SAD	WC	WHR	WHtR	BMI	SAD	WC	WHR	WHtR
Men (n = 389)										
FPG	0.20 (0.006)	0.21 (0.004)	0.27 (<0.001)	0.25 (0.001)	0.23 (0.001)	0.17 (0.019)	0.23 (0.002)	0.20 (0.006)	0.21 (0.003)	0.19 (0.010)
PLG	0.28 (<0.001)	0.35 (<0.001)[2]	0.32 (<0.001)[2]	0.28 (<0.001)[2]	0.35 (<0.001)	0.13 (0.078)	0.14 (0.051)	0.14 (0.062)	0.12 (0.099)	0.18 (0.014)
HbA_{1c}	0.09 (0.196)	0.10 (0.159)	0.16 (0.022)	0.18 (0.012)[2]	0.14 (0.059)	0.11 (0.123)	0.16 (0.032)	0.08 (0.275)	0.00 (0.972)	0.11 (0.133)
Ln TG	0.31 (<0.001)	0.33 (<0.001)	0.39 (<0.001)[2]	0.41 (<0.001)[2]	0.39 (<0.001)[2]	0.19 (0.011)	0.31 (<0.001)	0.17 (0.017)	0.17 (0.020)	0.17 (0.020)
HDL-C	−0.21 (0.004)	−0.23 (0.001)	−0.27 (<0.001)	−0.24 (0.001)	−0.24 (0.001)	−0.26 (<0.001)	−0.21 (0.004)	−0.18 (0.012)	−0.07 (0.316)	−0.15 (0.041)
SBP	0.09 (0.207)	0.24 (0.001)	0.16 (0.024)	0.19 (0.007)	0.14 (0.053)	0.19 (0.008)	0.18 (0.012)	0.16 (0.026)	0.16 (0.028)	0.18 (0.015)
DBP	0.07 (0.326)	0.18 (0.014)	0.14 (0.048)	0.12 (0.103)	0.09 (0.188)	0.14 (0.056)	0.09 (0.239)	0.11 (0.135)	0.06 (0.406)	0.09 (0.228)
Women (n = 437)										
FPG	0.27 (<0.001)	0.37 (<0.001)	0.33 (<0.001)	0.31 (<0.001)	0.35 (<0.001)	0.34 (<0.001)	0.36 (<0.001)	0.40 (<0.001)	0.39 (<0.001)	0.39 (<0.001)
PLG	0.10 (0.122)[2]	0.14 (0.035)[2]	0.17 (0.011)[2]	0.26 (<0.001)[2]	0.21 (0.001)[2]	0.29 (<0.001)	0.31 (<0.001)	0.33 (<0.001)	0.33 (<0.001)	0.32 (<0.001)
HbA_{1c}	0.19 (0.004)	0.15 (0.024)	0.21 (0.002)	0.13 (0.053)	0.20 (0.002)	0.20 (0.005)	0.19 (0.006)	0.25 (<0.001)	0.23 (0.001)	0.23 (0.001)
Ln TG	0.26 (<0.001)	0.39 (<0.001)	0.36 (<0.001)	0.41 (<0.001)	0.37 (<0.001)	0.31 (<0.001)	0.38 (<0.001)	0.31 (<0.001)	0.37 (<0.001)	0.33 (<0.001)
HDL-C	−0.33 (<0.001)	−0.31 (<0.001)	−0.35 (<0.001)[2]	−0.28 (<0.001)	−0.32 (<0.001)	−0.23 (0.001)	−0.21 (0.003)	−0.29 (<0.001)	−0.35 (<0.001)	−0.28 (<0.001)
SBP	0.29 (<0.001)[2]	0.24 (<0.001)[2]	0.27 (<0.001)[2]	0.23 (<0.001)	0.31 (<0.001)[2]	0.16 (0.023)	0.13 (0.068)	0.15 (0.032)	0.15 (0.032)	0.15 (0.029)
DBP	0.38 (<0.001)[2]	0.30 (<0.001)[2]	0.37 (<0.001)[2]	0.31 (<0.001)[2]	0.39 (<0.001)[2]	0.19 (0.006)	0.18 (0.009)	0.13 (0.074)	0.13 (0.074)	0.12 (0.078)

[1] P value in parentheses; men aged <65 y, n = 196; men aged ≥65 y, n = 193; women aged <65 y, n = 231; women aged ≥65 y, n = 206. SAD, sagittal abdominal diameter; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio, FPG, fasting plasma glucose; PLG, postload glucose; HbA_{1c}, glycated hemoglobin; Ln TG, ln-transformed triacyglycerol; HDL-C, HDL cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure.

[2] Significant effect modification by age in linear regression model, $P < 0.10$.

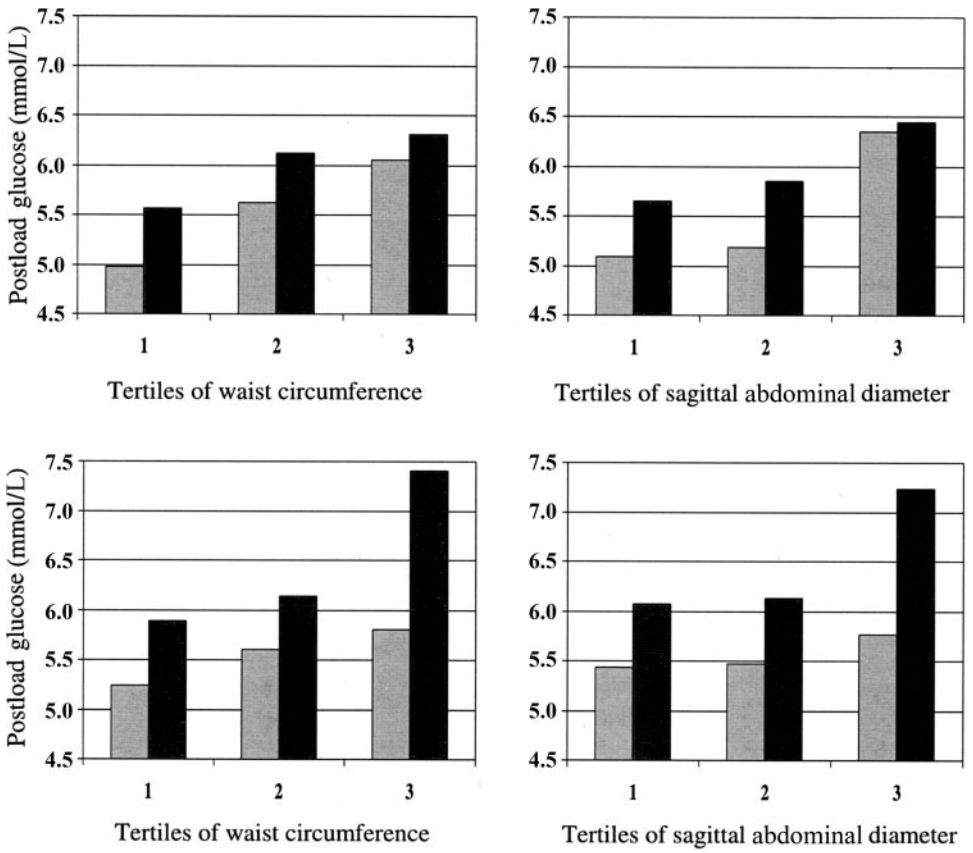

FIGURE 1. Mean postload glucose concentrations according to tertiles of waist circumference (left) and tertiles of sagittal abdominal diameter (right) in men (top) and in women (bottom). ▨, Subjects aged <65 y; ■, subjects aged ≥65 y. Waist × sex × age and sagittal abdominal diameter × sex × age interactions were statistically significant ($P = 0.032$ and $P = 0.038$, respectively).

but these exclusions did not materially change the results (data not shown). The results were also similar for all the other anthropometric measurements if subjects with missing sagittal abdominal diameter were not excluded from the analyses (data not shown).

The associations between waist circumference and postload glucose and between sagittal abdominal diameter and postload glucose are shown in **Figure 1**. They illustrate a stronger association in younger men and in older women. The association of WHR with postload glucose had a similar pattern (not shown).

After additional adjustment for BMI, the correlations between measures of abdominal adiposity and the components of the metabolic syndrome became considerably weaker (**Table 4**). Most anthropometric measures retained statistically significant correlations, however. An exception was the lack of correlation between anthropometric measures and blood pressure in the group aged ≥65 y. No single anthropometric measure was consistently more strongly correlated with components of the metabolic syndrome than with the other measures after additional adjustment for BMI.

Although the correlations were weaker in the group aged ≥65 y, it could be argued that, because they already have less favorable values of metabolic variables, subjects in the older age group will reach critical (high-risk) values of the metabolic variables at lower levels of abdominal obesity. However, no consistent differences between the older and younger age groups were observed in the waist circumference or sagittal abdominal diameter measurements at which critical values of metabolic variables were reached (data not shown). For example, elevated fasting glucose concentrations (ie, ≥6.1 mmol/L) are reached at a lower waist circumference in younger men (101 cm) than in older men (103 cm), whereas these concentrations are reached at a higher waist circumference in younger women (106 cm) than in older women (104 cm).

DISCUSSION

Few studies have examined the relation between different anthropometric measures and CVD risk factors in the elderly. As far as we know, this is the first study to examine and compare all the simple anthropometric measurements, including sagittal abdominal diameter, in relation to the components of the metabolic syndrome in an elderly population. We found that no single anthropometric measure was consistently superior in indicating unfavorable levels of components of this syndrome. Correlations were generally stronger in the younger (<65 y old) men and women than in their older (≥65 y old) counterparts. In addition, stronger correlations were observed in women than in men.

Even though our data are derived from a cross-sectional study, the sex- and age-related differences in weight and stature seem to correspond to those described in some longitudinal studies (28, 29). Our study also confirms the observation that body fat distribution differs significantly between the sexes in the elderly. Our results show that the various anthropometric measurements are significantly associated with components of the metabolic

TABLE 4
Age- and BMI-adjusted Pearson correlations between anthropometric measurements and components of the metabolic syndrome stratified for age and sex[1]

	Aged <65 y				Aged ≥65 y			
	SAD	WC	WHR	WHtR	SAD	WC	WHR	WHtR
Men (n = 389)								
FPG	0.10 (0.172)	0.20 (0.006)	0.17 (0.021)	0.13 (0.072)	0.16 (0.027)	0.11 (0.152)	0.15 (0.038)	0.09 (0.246)
PLG	0.22 (0.002)[2]	0.17 (0.021)[2]	0.15 (0.039)[2]	0.22 (0.002)	0.08 (0.265)	0.06 (0.446)	0.07 (0.360)	0.13 (0.075)
HbA_{1c}	0.05 (0.481)	0.17 (0.016)	0.16 (0.031)[2]	0.12 (0.104)	0.11 (0.129)	−0.02 (0.802)	−0.06 (0.414)	0.03 (0.683)
Ln TG	0.16 (0.026)	0.25 (0.001)[2]	0.30 (<0.001)[2]	0.26 (<0.001)[2]	0.26 (<0.001)	0.04 (0.578)	0.09 (0.213)	0.03 (0.686)
HDL-C	−0.12 (0.085)	−0.18 (0.013)	−0.15 (0.035)	−0.12 (0.103)	−0.07 (0.330)	0.04 (0.548)	0.06 (0.406)	0.12 (0.113)
SBP	0.25 (0.001)	0.17 (0.018)	0.17 (0.015)	0.13 (0.072)	0.08 (0.248)	0.01 (0.890)	0.08 (0.299)	0.03 (0.671)
DBP	0.18 (0.014)	0.17 (0.020)	0.09 (0.195)	0.07 (0.330)	0.00 (0.972)	−0.01 (0.944)	−0.01 (0.914)	−0.05 (0.511)
Women (n = 437)								
FPG	0.26 (<0.001)	0.20 (0.002)	0.22 (0.001)	0.23 (<0.001)	0.18 (0.009)	0.22 (0.002)	0.26 (<0.001)	0.21 (0.004)
PLG	0.09 (0.154)[2]	0.15 (0.029)[2]	0.24 (<0.001)[2]	0.23 (0.001)	0.16 (0.027)	0.17 (0.018)	0.22 (0.001)	0.15 (0.032)
HbA_{1c}	0.02 (0.765)	0.09 (0.159)	0.05 (0.412)	0.09 (0.191)	0.08 (0.259)	0.16 (0.027)	0.15 (0.031)	0.13 (0.073)
Ln TG	0.30 (<0.001)	0.26 (<0.001)	0.34 (<0.001)	0.28 (<0.001)	0.24 (0.001)	0.11 (0.121)	0.26 (<0.001)	0.13 (0.058)
HDL-C	−0.12 (0.075)	−0.16 (0.018)[2]	−0.17 (0.012)	−0.11 (0.111)	−0.07 (0.348)	−0.17 (0.016)	−0.28 (<0.001)	−0.16 (0.027)
SBP	0.05 (0.416)[2]	0.07 (0.273)[2]	0.12 (0.062)	0.13 (0.060)[2]	0.03 (0.711)	0.03 (0.649)	0.07 (0.298)	0.03 (0.660)
DBP	0.05 (0.451)[2]	0.13 (0.053)[2]	0.17 (0.009)[2]	0.15 (0.029)[2]	0.07 (0.338)	−0.07 (0.334)	−0.03 (0.645)	−0.09 (0.185)

[1] P values in parentheses. Men aged <65 y, n = 196; men aged ≥65 y, n = 193; women aged <65 y, n = 231; women aged ≥65 y, n = 206. SAD, sagittal abdominal diameter; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio, FPG, fasting plasma glucose; PLG, postload glucose; HbA_{1c}, glycated hemoglobin; Ln TG, ln-transformed triacylglycerol; HDL-C, HDL cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure.

[2] Significant effect modification by age in linear regression model, $P < 0.10$.

syndrome in a general elderly population but that no single measure was consistently superior to another. Of all of the anthropometric measurements, the BMI is the most frequently used. However, the relation between BMI and body fatness is dependent on age (30). Weight may remain stable in the elderly, whereas fat-free mass decreases (eg, sarcopenia) and fat mass increases (31). In addition, the body fat distribution changes with age (from peripheral to abdominal fat distribution), but that change is not captured by the BMI. Therefore, BMI would be expected to be a poor indicator of CVD risk in the elderly. In the population of the current study, however, BMI actually performed well as compared with the other anthropometric measures. It could be argued that this finding resulted from our exclusion of subjects who were taking antidiabetic, antihypertensive, or lipid-lowering medication, which left a relatively healthy population for the current study. However, if these subjects taking medication were not excluded, the results were the same. Note that the results may be different in even older populations (>75 y old). Moreover, we observed that measures of abdominal body fatness were still substantially associated with various other components of the metabolic syndrome after adjustment for BMI. This finding indicates that the use of measures of fat distribution may provide useful information in addition to BMI for the prediction of the metabolic syndrome in the elderly. In our data, however, BMI does not significantly contribute to the metabolic risk if waist circumference or sagittal abdominal diameter is used (except for blood pressures in women) (data not shown). These results suggest that, for public health purposes, a sagittal abdominal diameter or a (more easily obtained) single waist circumference could be used in the elderly.

The relative utility of various estimates of fat distribution has been controversial. Some investigators have proposed that waist circumference is a better indicator of abdominal fat distribution than is WHR, because it requires only one measurement and is more highly correlated with visceral fat (14, 15). Sagittal abdominal diameter has been proposed to be even better; however, no large or consistent difference between sagittal abdominal diameter and waist circumference has been found in relation to visceral fat (15, 32–35). In men and women somewhat older than those in the current study (ie, >70 y old), sagittal abdominal diameter was a better predictor of visceral fat than was waist circumference, and BMI performed just as well as did waist circumference (36). Studies comparing all these anthropometric measures with cardiovascular disease risk rather than with visceral fat are, however, scarce. In small studies in obese men (37) and healthy normal-weight men (38), sagittal abdominal diameter was (slightly) more strongly correlated with metabolic variables than was the waist circumference, WHR, or BMI. In another small study of selected men (of whom 50% had type 2 diabetes and 50% were of Indo-Asian origin), sagittal abdominal diameter and waist circumference were better predictors of an adverse metabolic profile than were WHR and BMI (39). A study including both men and women showed that sagittal abdominal diameter was slightly but consistently more strongly correlated with cardiovascular disease risk than were waist circumference, WHR, and BMI (40), but another study showed both sagittal abdominal diameter and waist circumference to be more strongly correlated than was WHR (32). Inconsistency among studies may be caused by differences between characteristics of the study populations. All of these studies were performed in relatively young subjects. Only one previous study was performed in older men and women (aged 67–78 y), and it also found that no single anthropometric measure was consistently more strongly correlated with metabolic outcomes than were the others (41). After adjustment for BMI, that study found that sagittal abdominal diameter and waist circumference were the strongest correlates (41).

In our study, all abdominal anthropometric measures were correlated with metabolic disturbances, but none was superior

to the other in predicting these disturbances, either before or after adjustment for BMI. Most of the correlations were somewhat stronger in the younger (<65 y old) than in the older (≥65 y old) subjects, as was found previously (42). This finding may indicate that, during aging, additional changes occur in body composition that are not captured by the anthropometric measures used. These changes in body composition may include sarcopenia with concomitant fat accumulation, intermuscular or intramuscular fat accumulation, or liver fat accumulation, all of which have been shown to be related to an adverse metabolic profile.

In conclusion, no single anthropometric measure, including sagittal abdominal diameter, was consistently superior to the other anthropometric measures in indicating unfavorable levels of components of the metabolic syndrome in older men and women. From a public health perspective, it may be advisable to use the anthropometric measurement that is regarded as the simplest and most practical, such as the waist circumference, in an elderly population. Further research should be undertaken to confirm whether these results also apply to older men and women of other ethnicities or to more elderly (eg, ≥80 y old) persons.

JM-P and MBS were responsible for the data analyses; JM-P wrote the draft of the manuscript, and MBS was responsible for the final version; RMvD, JMD, LMB, CDAS, RJH, GN, and JCS were involved in the presentation and interpretation of the results. None of the authors had a personal or financial conflict of interest.

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